RIVERSIDE OXBOW
FORT WORTH, TEXAS

CHAPTER 4
PLAN FORMULATION

According to U.S. Army Corps of Engineers' Policy and Planning Guidance for Conducting Civil Works Planning Studies (ER 1105-2-100), ecosystem restoration projects should be formulated in a systems context to improve the potential for long-term survival of aquatic, wetland, and terrestrial complexes as self-regulating, functioning systems. This chapter details the steps that were taken to formulate a plan that meets the guidance, considers the constraints, and best meets or exceeds the Riverside Oxbow study planning objectives as set forth below. Alternative measures were identified and the beneficial and adverse contributions of each alternative measure were then evaluated against existing and future without project conditions. Finally, the remaining alternative measures were compared against each other using cost effectiveness and incremental analyses.

OBJECTIVES

Based on the existing conditions investigations, the local, regional, state, and national problems identified and with input from resource agencies, the general public, the local sponsor, and study team members, the following planning objectives were developed for the Riverside Oxbow study area. These objectives include:

- Improve the quality and increase the quantity of the riparian and bottomland hardwood habitat for the benefit of multiple species of birds and wildlife;
- Improve the quality and increase the quantity of the emergent wetland habitat to restore nesting, brood rearing, and wintering habitat for multiple species birds and wildlife;
- Reestablish a contiguous riparian corridor to allow unobstructed migration of avian and wildlife species;
- Restore a more natural hydrologic regime;
- Restore and improve aquatic habitat for fish and other aquatic organisms;
- Improve and restore habitat for migrant neotropical birds and waterfowl, as well as residential wildlife species;
- Reduce the fragmented nature of the bottomland hardwood habitat;
- Provide a sustainable level of food, nesting, and cover for all wildlife communities;
- Protect and buffer the riparian habitat from adjacent land uses and encroaching development activities;
- Restore the stability, function, and dynamic processes of the floodplain to a more natural, less degraded condition;
- Protect and increase habitat diversity and the interspersion of habitat types, including the remnant prairie habitat and associated drainages of Tandy Hills;
- Improve the water quality in conjunction with other ecosystem restoration activities; and,

- Improve the aesthetics, as well as the recreational and educational opportunities that are compatible with ecosystem restoration activities for a wide variety of interests.

CONSTRAINTS

The study team identified several constraints within the study area that had significant impacts on the types, methods, and/or scales of restoration activities that could be implemented. These constraints included:

- CDC and ROD hydrologic and hydraulic criteria apply – no increase in 100-year and SPF water surface elevations and no loss of valley storage for the 100-year flood discharges and no more than 5 percent loss for the SPF discharge;
- The location of Interstate Highway 30, which bisects a portion of the study area;
- The location of commercial businesses in the real estate tracts north of the oxbow;
- The location of residential homes in the real estate tracts in and adjacent to the Tandy area;
- The city of Fort Worth's Recreation Master Plan for the existing and potential future lands within and adjacent to Gateway Park;
- Avoid and/or minimize adverse impacts to identified archeological or buried cultural resources;
- Avoid and/or minimize clean up of any identified hazardous or contaminated sites;
- Minimize required operation and maintenance efforts and expenses;
- Prior commitments and agreements between the local sponsor and adjacent landowners within the study area;
- Previous Section 404 permitted activities and associated hydraulic and hydrologic mitigation requirements in and/or adjacent to the study area;
- Recommended plan must be supported by the local sponsor in order to facilitate implementation.

ECOSYSTEM RESTORATION MEASURES AND ALTERNATIVES

Measures are features or activities that can be implemented at specific sites to address one or more of the planning objectives. As the next step in the plan formulation process, the study team identified a variety of restoration measures and/or scales of measures for each zone in the study area. Since bottomland hardwoods, wetlands, grasslands, and aquatic habitats are identified as prevalent floodplain habitat types in the Prairies and Cross Timbers ecoregion, which encompasses the study area, the identification of restoration measures for each of these systems is discussed in the following paragraphs.

Any restoration activity requires some form of real estate interest. For the purposes of this feasibility study, fee title acquisition was determined to be the appropriate real property interest. As such, fee title costs are included in the plan formulation process for evaluating and comparing restoration measures by combining the annualized costs of real estate into the annualized costs for each of the restoration measures for each zone on a per acre basis.

The only exception to this is in the Tandy zone where the study team looked at several different scales of land acquisition, each having unique restoration opportunities.

The restoration measures discussed below have been numbered in order to help identify those measures in further discussions and reference tables..

BOTTOMLAND HARDWOODS. Several of the planning objectives established for this study rely upon reforestation of bottomland hardwoods or habitat improvements to existing bottomland hardwood tracts as restoration methods. For the purposes of this study, reforestation measures are those activities that would be implemented to convert existing non-wooded habitat types to bottomland forest stands, while habitat improvement measures are those activities undertaken within existing bottomland hardwood stands to improve the quality of the habitat.

Reforestation of Bottomland Hardwoods – Coverage Density (Measure 1A). While reforestation of the entire floodplain would help meet several of the planning objectives, reforestation in the study area would also affect hydraulic efficiency and could potentially impact the 100-year and SPF water surface elevations and valley storage criteria established by the CDC program. In order to quantify these impacts and optimize the extent of reforestation that could be undertaken in the area, hydraulic models were developed to evaluate the potential impacts that different levels of reforestation would have on water surface profiles. The levels of reforestation were based on - 10, 25, 50, and 100 percent tree cover densities. Each hydraulic model developed for the increasing levels of reforestation produced increased water surface elevations, as compared to the West Fork baseline conditions. The increases were caused by the additional roughness in the floodplain due to the increase in tree coverage. Once the increases in water surface elevation were established, the level of hydraulic mitigation required to offset any rise in water surface elevations was developed (models included the most efficient method of hydraulic mitigation, which is to remove, or excavate, material along the banks of the river channel.)

Table 4
Summary of Tree Coverage Densities to Water Surface Elevations and Potential Hydraulic Mitigation Requirements

Tree Coverage Densities	Range of 100-year Flood Water Surface Elevation Increases	Required Hydraulic Mitigation (Cubic Yards of Excavation)
10 percent	0.2 – 0.3 feet	100,000 cy
25 percent	0.4 – 0.5 feet	350,000 cy
50 percent	0.6 – 0.7 feet	580,000 cy
100 percent	0.8 – 1.2 feet	730,000 cy

While the table seems to indicate that any of the alternative tree cover densities would be viable, excavation in excess of 100,000 cubic yards (cy) requires excessive widening of the existing modified channel, or would require channel modifications downstream of the confluence of the oxbow with the West Fork. Neither option is viable. Removing existing riparian vegetation to mitigate for adverse hydraulic impacts of adding new vegetation would be counterproductive. Any excavation beyond 100,000 cy would necessitate the relocation of an 84-inch sewerage line, which would significantly increase project costs. Further, since the river channel in this area has not been modified and is in its natural alignment and condition, environmental mitigation would be required for any adverse impacts to the channel. U.S. Army Corps of Engineers policy and guidance (ER 1105-2-100) does not allow for ecosystem restoration requiring fish and wildlife mitigation. Therefore, reforestation of bottomland hardwoods is constrained by required hydraulic mitigation to the 10 percent level.

Reforestation of Bottomland Hardwoods – Corridor Width (Measure 1B). Another reforestation parameter considered is corridor width. One of the project objectives is to establish or maintain some minimum width of continuous riparian corridor throughout the project area. A literature review conducted by resource professionals to determine the optimal width of the riparian corridor for the study area, indicate that a riparian zone of less than 50 meters (approximately 165 feet) does not provide suitable habitat for many of the neotropical migrants. Riparian zones of 100 to 150 meters (approximately 330 to 495 feet, respectively) are sufficient to maintain functional assemblages of the six most common species of breeding neotropical migratory birds. A riparian corridor of 100 to 150 meters will provide sufficient breeding habitat for area-sensitive forest birds and have more abundant populations of neotropical migrants than riparian areas of less width, which are inhabited mainly by resident or short-distance migrants.And, finally, riparian zone of at least 500 meters (approximately 1650 feet) is necessary to maintain the complete avian community. Using this information, resource specialists determined that the riparian corridor needed to be at least 100 meters wide, and preferably 500 meters wide, to significantly improve habitat benefits for multiple avian and wildlife species.

A real estate evaluation for these two reforestation measures determined that the 100-meter wide corridor would not require relocation of any of the commercial businesses located west and north of the oxbow channel, while implementation of a 500-meter wide corridor would require the acquisition and relocation of a number of businesses. This would substantially increase the real estate costs of the proposed project. In addition, implementation of a 500-meter wide riparian corridor would require planting approximately 200 acres of additional trees in the study area, which is well above the 10 percent limit established for reforestation efforts in the study area. The number of acres requiring reforestation for a 100-meter riparian corridor would be approximately 20 acres, well within the 10 percent limit. Therefore, the goal of restoration efforts for the riparian corridor in the study area was established as a riparian zone of at least 100 meters wide, where possible.

Reforestation of Bottomland Hardwoods – Planting Densities and Materials (Measure 1C). The density of plantings, the type of the plant material, and the size of the planting stock for the trees and shrubs would have an impact on the level of restoration, especially in the short term. The size of the plants can range from seeds and acorns to seedlings to containerized stock. Evaluation of different scales of planting densities, types of plant materials, and size of plant stocks is based on recommendations from resource specialists. These scales were then included in cost effectiveness and incremental analyses to determine which reforestation scale would provide the most habitat gains for the cost of implementation. The following reforestation scales were evaluated:

- No action (R0)
- 60 one-inch caliper containerized trees, 30 one-gallon containerized shrubs, and 100 seedlings per acre (R1)
- 40 one-inch caliper containerized trees, 20 one-gallon containerized shrubs, and 150 seedlings per acre (R2)
- 20 one-inch caliper containerized trees, 10 one-gallon containerized shrubs, and 200 seedlings per acre (R3)
- 300 bare root tree seedlings and 150 bare root shrub seedlings per acre (R4)

A variety of combination plans were ultimately evaluated using these variations on reforestation density/material parameters. Results are included in a subsequent section of this chapter.

Improvement of Existing Bottomland Hardwood Habitat (Measure 2). There are currently approximately 300 acres of bottomland hardwood habitat in the study area. USFWS and Corps biologists conducted Habitat Evaluation Procedure (HEP) on sample plots using habitat suitability models for specific species that represent the guilds for each vegetation type, including riparian hardwoods. The field data were used to identify the limiting factors and to compute a numeric value for the existing habitat quality. Primary limiting factors for the riparian or bottomland hardwoods are lack of hard mast, lack of soft mast (fruits), proliferation of non-native species in the understory layers, dense thickets that preclude bird of prey movement and prohibit regeneration of climax vegetation, and lack of cavities in hardwood trees.

Habitat improvement measures identified include planting of hard- and soft-mast producing trees and shrubs, placing of nesting boxes for wood ducks and other bird species, and application of forest management techniques such as selective thinning to remove non-natives and understory vegetation. The following range of habitat improvement scales was evaluated:

- No action (H0)
- 10 one-inch caliper containerized trees, 7 one-gallon containerized shrubs and forest management techniques (thinning, nesting boxes, etc.) per acre (H1)
- 5 one-inch caliper containerized trees, 5 one-gallon containerized shrubs and forest management techniques (thinning, nesting boxes, etc.) per acre (H2)
- 2 one-inch caliper containerized trees, 2 one-gallon containerized shrubs and forest management techniques (thinning, nesting boxes, etc.) per acre (H3)

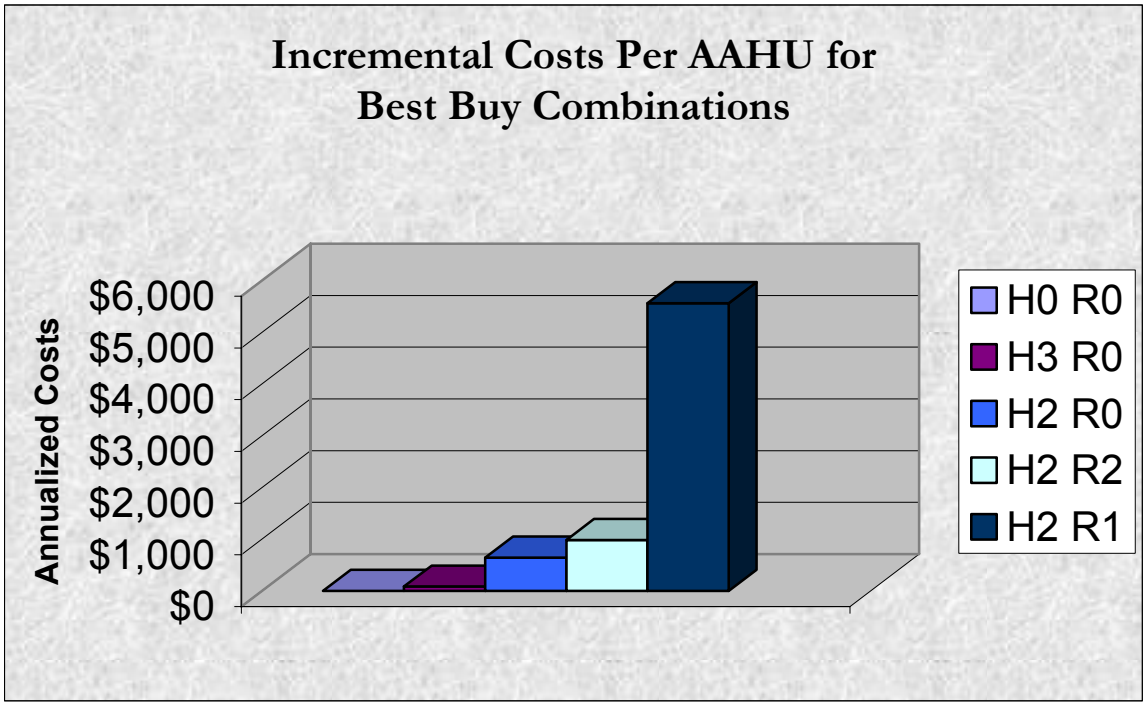
Reforestation/Habitat Improvement "Best Buy" Combinations. Comparative analysis techniques (Robinson et al. 1990) were used to determine the most cost effective combinations of scales for reforestation and habitat improvement. For each of the measures and scales identified above, a "no action" measure was developed. Annualized habitat unit gains for each measure/scale and the no action counterparts were computed over the 50-year life of the project. Annualized costs, including operations and maintenance costs, were computed for each of the measures and their "no action" counterparts. These data were then input into IWR-Plan: Decision Support Software, Version 3.3 to determine cost effectiveness and incremental cost analyses. Results of the analysis identifying the best buy combinations and associated incremental costs are shown in Table 5.

Table 5
Incremental Cost of Best Buy Combinations for Reforestation and Habitat Improvement Scales

Scale	AAHUs	Incremental AAHUs	Annualized Costs	Incremental Annualized Costs	Average Cost Per AAHU	Incremental Cost Per Output
H0 R0	43.25	43.25	$0	$0	$0.00	$0
H3 R0	108.99	65.74	$5,563	$5,563	$51.04	$84.62
H2 R0	122.83	13.84	$14,463	$8,900	$117.75	$643.06
H2 R2	166.93	44.1	$57,772	$43,309	$346.09	$982.06
H2 R1	168.33	1.40	$65,555	$7,783	$389.44	$5,559.29

Figure 6 depicts the AAHUs and annualized costs for all the best buy combinations for reforestation and habitat improvement scales. Based on this analysis, the study team determined that the best buy combination H2 R2 is the combination of choice. Therefore, all further discussion or evaluation of reforestation and bottomland hardwood habitat improvement measures in this study are based on this optimized combination. The reforestation measure includes 40 one-inch caliper containerized trees, 20 one-gallon containerized shrubs, and 150 seedlings per acre. The bottomland hardwood habitat improvement measure includes 5 one-inch caliper containerized trees, 5 one-gallon containerized shrubs and forest management techniques (selective thinning, nesting boxes, etc.) per acre.

Figure 6
Best Buy Combinations for Reforestation and Habitat Improvement Scales



WETLANDS. Several of the planning objectives identify restoration of wetland habitat as a key component. As with the bottomland hardwoods, opportunities to improve wetland habitat across the study area are found both through creation of new wetland complexes and improvement to existing wetlands. Both strategies are discussed below.

Creation of Wetlands – Size (Measure 3A). One of the measures considered to improve the quality and increase the quantity of wetlands in the study area includes the creation of new wetland complexes. In identifying potential locations for the construction of new wetland complexes, the study team identified sites that had the greatest potential to mimic the functional value and dynamic processes of wetland habitat that would have existed within the Trinity River's floodplain under historic conditions. Two sites were determined to be suitable for development of new wetland complexes. The first site is an old remnant scar of Sycamore Creek in the Oxbow Center zone. This remnant defines the original channel of Sycamore Creek near its confluence with the natural channel of the West Fork prior to the construction of the modified channel between Riverside Drive and the confluence of the oxbow and the West Fork downstream of Beach Street. Currently there are several scattered large pecan trees along this old river meander. In evaluating the development of a wetland complex in this area, the study team looked at three different sizes for the complex – 5.1 acres, 12.3 acres, and 17.8 acres, respectively, utilizing to a varying degree the topography of the old remnant meander.

Both the 5.1-acre and 12.3-acre wetland complexes could be constructed within the remnant scar where the topography is lower than the surround lands, thereby minimizing the quantity of excavation needed and limiting construction costs. Proportionally, the 17.8-acre complex would require increased amounts of excavation for its size. According to resource specialists, the relatively small size of the 5.1-acre wetland complex would not

allow for a wide variation in water depths which would in turn limit the vegetation types (emergent, submerged, floating, etc.) and subsequently the variety and quantity of waterfowl and shore birds it would support. It was determined that each of the two larger complexes evaluated could be constructed with a deeper water pond and several smaller shallower water cells. The deeper pond would serve as holding tank for water that could then be disbursed to shallower cells, as needed. The shallower cells would be constructed with maximum water depth of less than 3 feet, which would allow the development of emergent wetland vegetation that is utilized by a wide variety of aquatic and wildlife and bird species as sources for food, cover, and reproduction. The deeper water pond, with a maximum depth of 6 to 8 feet, would provide open water habitat needed by certain species of waterfowl and serve as a refuge site for aquatic organisms and a holding tank to supply water to the shallow cells during extended periods of drought. All these factors would increase the value of the wetland complex for a wide variety of waterfowl and shore birds. All three sizes were carried forward for further evaluation.

The second site identified for creation of a wetland complex is in the old wastewater treatment drying beds located in Gateway East. As with the remnant scar of Sycamore Creek, the use of the drying beds to construct a wetland complex would minimize the amount of excavation needed and, therefore, the costs of implementation. Again, the study team evaluated 3 different sizes of wetland complexes for this site – 15.0 acres, 26.8 acres, and 35.0 acres, respectively, mostly utilizing the topography of the existing drying beds. Both the 15-acre and 26.8-acre complexes could be constructed generally within the confines of the drying bed boundaries, although the 26.8-acre wetland would also utilize a low-lying area north of the uppermost bed. Creation of the 35-acre wetland complex was quickly dropped from consideration in the formulation process for this site when it became apparent that construction of a complex this size would not only incur proportionally greater costs for excavation, but would also cause adverse impacts to some existing bottomland hardwood tracts. A wetland complex of either the 15.0-acre or 26.8-acre size would maximize the use of the topography within the existing drying beds. Both the 15.0 and 26.8-acre wetland sizes were carried forward for further evaluations.

Creation of Wetlands – Water Control and Plantings (Measure 3B). Construction of any of the different sizes of wetland complexes discussed above could include the planting of native wetland vegetation and the addition of water control structures. The planting of wetland vegetation would help to eliminate the prolific growth of weedy species that are often the first plant species to colonize an area following a period of disturbance, such as the construction activities associated with creation of a wetland complex. In addition, adding endemic wetland plant material provides seed sources and propagules for continued growth and expansion of this quality wetland vegetation as the wetland complex matures.

The addition of water control structures would allow manipulation of water levels and retention time to promote the growth of quality wetland vegetation. One unique feature in the Gateway East zone is a u-shaped wetland located north of the drying beds. This wetland, which is located adjacent to some better quality woodlands, is an old naturally occurring oxbow remnant that receives water from the West Fork of the Trinity River during periods of high flows. Currently, the oxbow contains water only during the wet season. The location of debris and the flow patterns through soft-stemmed vegetation following a significant rain event indicate that water enters the oxbow through a small

channel from the riverbank under an existing concrete sidewalk. Analysis of the topography of the Gateway East zone indicates that the flow of water from the created wetlands in the old drying beds could be drained north toward the u-shaped wetlands with the addition of a water control structure. The addition of this water control structure would improve the hydrologic regime of the u-shaped wetland by providing a reliable water source. Since fish and amphibians are known to utilize the oxbow wetland, this would not only improve the quality of wetland habitat, but also improve the quality of aquatic habitat. The addition of a water control structure to connect the u-shaped wetlands to the created wetland complex in the Gateway East zone was incorporated as a component of the created wetland plans for analysis.

Creation of Wetlands – Water Source (Measure 3C). Most of the existing wetlands and ponds in the Riverside Oxbow study area are very ephemeral in nature. Many dry up completely in the long, dry Texas summers. Even the largest of them have been so reduced in size following periods of sustained drought that they no longer provide wetland habitat. The primary reason for this is the implementation of reservoirs and flood control projects upstream of the project area that control flooding to such an extent that out of bank flooding is relatively infrequent. One of the measures identified for improving the quality of wetland habitat in the study area is to provide a reliable water source by pumping water out of the river channel as necessary. There are two methods of doing this. One option would be to use portable pumps and pipes. A second option would be the construction of permanent pump stations with pumping equipment specifically design for the individual wetland complex. According to the resource specialists, the habitat benefits of water pumping would be slightly greater for a permanent pumping station since these stations would be built into the ground which would minimize potential adverse noise impacts, trash and debris collection problems, and potential safety concerns that would be expected with mobile pumps and flexible hose or pipes lying on the ground. However, the primary difference between these two options is in their life-cycle costs. When annualized costs were computed, the permanent pump is slightly less costly over the 50-year life of the project than the temporary pump option. Table 6 presents the results of the analysis of the annualized costs associated with the two alternative water source options including operation and maintenance costs. Based on the results of the analysis, permanent water source stations were determined to be the most cost effective water source option. All further discussion or analysis of water supply as a wetland restoration measure and/or scale in this report assumes the construction of a permanent water supply station.

Table 6
Annualized Cost Analysis for Alternative Water Sources for Created and Improved Wetlands

INVESTMENT COST	PERMANENT PUMP	TEMPORARY PUMP
First Cost	$58,449	$19,361
Annual Interest Rate (decimal)	0.6125	0.6125
Project Life (years)	50	50
Construction Period (months)	12	12
Interest During Construction	$1,922	$637
Investment Cost	$60,371	$19,998
AVERAGE ANNUAL CHARGES		
Interest	$3,698	$1,225
Amortization	$199	$66
Operations and Maintenance	$500	$2,000
Replacements	$0	$1,162
TOTAL ANNUAL CHARGES	**$4,397**	**$4,453**

The scales for the restoration of created wetland complexes in Oxbow Center and Gateway Beach are detailed below.

Oxbow Center:
- No action (A0)
- Create a 5.1 acre wetland (A1)
- Create a 12.3 acre wetland (A2)
- Create a 17.8 acre wetland (A3)
- Create a 5.1 acre wetland plus water control and plantings (A4)
- Create a 12.3 acre wetland plus water control and plantings (A5)
- Create a 17.8 acre wetland plus water control and plantings (A6)
- Create a 5.1 acre wetland plus water control, plantings, and water source (A7)
- Create a 12.3 acre wetland plus water control, plantings, and water source (A8)
- Create a 17.8 acre wetland plus water control, plantings, and water source (A9)

Gateway Beach:
- No action (A0)
- Create a 15 acre wetland (A1)
- Create a 26.8 acre wetland (A2)
- Create a 15 acre wetland plus water control and plantings (A4)
- Create a 26.8 acre wetland plus water control and plantings (A5)
- Create a 15 acre wetland plus water control, plantings, and water source (A7)
- Create a 26.8 acre wetland plus water control, plantings, and water source (A8)

Because the size of the wetland complexes would impact the number of acres available for other potential restoration within the Oxbow Center and Gateway Beach zones, interim analyses were conducted to determine the most cost effective wetland restoration measures for both sites. For each of the measures and scales identified above, a "no action" measure

was developed. Next annualized habitat unit gains for each measure/scale and the no action counterparts were computed over the life of the project, including operations and maintenance costs. This data was then input into the IWR-Plan comparative analysis model. Tables 7 displays the average annual habitat units and annualized costs for each of the wetland complex measures input into the analyses in Oxbow Center and Gateway East, respectively, and the incremental costs per output for the "best buy" combination of measures or scales.

Table 7
Incremental Cost of Best Buy Combinations for Created Wetland Complexes

	Oxbow Center			Gateway East		
Measure or Scale	**AAHUs Gained**	**Annualized Costs**	**Average Annual Cost/HU**	**AAHUs Gained**	**Annualized Costs**	**Average Annual Cost/HU**
Small wetland (A1)	1.54	$5,850	$3799	4.51	$22,445	$4977
Medium wetland (A4)	3.70	$12,696	$3431	8.07	$39,422	$4885
Large wetland (A7)	5.36	$23,617	$4406	10.53	$57,803	$5489
Small wetland + plantings & water control (A2)	2.87	$8,821	$3073	8.44	$27,876	$3302
Medium wetland + plantings & water control (A5)	7.66	$16,857	$2201	16.70	$45,350	$2715
Large wetland + plantings & water control (A8)	11.09	$29,418	$2653	21.63	$64,677	$2990
Small wetland, plantings, water control + water supply (A3)	3.45	$13,015	$3772	10.15	$29,721	$2928
Medium wetland, plantings, water control + water supply (A6)*	10.94	$21,115	$1930	23.84	$47,272	$1983
Large wetland, plantings, water control + water supply (A9)*	15.84	$33,676	$2126	31.14	$66,523	$2136

* Best Buy combinations

Based on the cost effectiveness and incremental analyses of wetland measures and scales, the study team determined that, for both sites, combination A6, or the medium-sized wetland with plantings, water control, and water supply was the combination of choice. Specifically, the optimized wetland complex in Oxbow Center would be 12.3 acres in size and the wetland complex in Gateway Beach would be 26.8 acres in size. Both complexes would include a water control structure(s), wetland plantings, and a permanent water

supply to be used as necessary to protect the functional integrity of the wetlands during extended periods of drought.

Improvement of Existing Wetland Habitat. Remnant wetlands are currently found in several locations throughout the study area. These wetland complexes are highly impacted and significant potential exists to improve the habitat they provide using a variety of strategies discussed below.

Improvement of Existing Wetland Habitat – Recontouring (Measure 4A). The modification of two ponds in the Gateway Beach zone would improve the quality of wetland habitat in the study area. Recontouring the edges of these water bodies to establish more shallow slopes and terraces would expand the acreage of wetland vegetation.

Improvement of Existing Wetland Habitat – Recontouring of Wetlands Plus Water Control and Plantings (Measure 4B). The addition of a water control structure between the two ponds in the Gateway Beach zone would allow manipulation of water levels to maximize wetland vegetation growth and hydraulically connect the two cells. Planting quality wetland vegetation in the shallow zones and modification of the forested vegetation surrounding the wetlands to remove some non-native species, plant some hard- and soft-mast producers, and thin the understory to more natural conditions would help to restore food, cover, and reproductive habitat for multiple species of wildlife and birds.

Improvement of Existing Wetland Habitat – Recontouring of Wetlands With Water Control and Plantings Plus Water Supply (Measure 4C). Just as improvements to created wetland complexes were evaluated for the addition of water supply so was this component evaluated for the existing ponds in the Gateway Beach zone. Under typical conditions in the midst of the long, hot, dry summers in Texas, the smaller of these two ponds is often dry and the larger one is greatly reduced in size. These wetlands are not able to support as great a population of aquatic, wildlife, and bird species as during the typical winter months when rainfall and thus water supply is more plentiful. Based on the cost analysis outlined in Table 5, the permanent water pump station was the water supply measure included in further analysis.

Improvement of Existing Wetland Habitat – Recontouring of Wetlands With Water Control, Plantings, and Water Supply Plus Removal of Old Gateway Park Road (Measure 4D). The location of the park entrance road off Beach Street serves as a barrier to a natural hydraulic connection between the wetlands in the zone and the oxbow to the south. Personnel from the Fort Worth Parks and Community Services Department stated that there are future plans to move the entrance road to Gateway Park. When this is completed a portion of the old park entrance road would become obsolete. One of the measures identified by the study team to improve the quality of the wetland habitat in the Gateway Beach zone would be to remove this road bed once the new entrance to Gateway Park is constructed and restore the hydraulic connection between the wetlands in the zone and the oxbow.

Improvement of Existing Wetland Habitat – Adding a Water Control, Structure (Measure 4E). During existing conditions surveys, resource specialists identified one location where the addition of a water control structure would improve the quality of

existing wetland habitat. This site is the pond located north of the oxbow east of Beach Street in the Oxbow North zone.

The placement of a water control structure with a spillway in the large pond located west of Beach Street and north of the oxbow would allow for water levels to be manipulated maximizing the growth of wetland vegetation. Besides restoring wetland benefits to the area, this pond also provides water quality benefits to the oxbow by capturing much of the local runoff from residential neighborhoods north of the oxbow that runs along the west side of Beach Street.

Analyses of the Gateway Beach wetland habitat improvements measures outlined above were included in the overall analyses for the study area, as was analysis of adding a water control structure to the North Pond in Oxbow North.

GRASSLANDS. In reviewing the vegetational history of the study area to identify restoration opportunities, resource specialists discovered that grasslands and grasslands with tree mottes made up a large portion of the floodplains. Not only would the addition of a grassland component mimic historical conditions, but it would also provide multiple habitat benefits and help to provide a sustainable source of food, nesting, and cover for multiple avian and wildlife species, both migrants and residential.

Grasslands – Buffer Strip along Riparian Corridor (Measure 5). During the literature review conducted by resource specialists several references included discussion of the benefits of grassland buffer strips either in conjunction with a wooded riparian component or as a stand-alone restoration measure, where applicable. A California study conducted by graduate students, Marc Los Huertos and Felicia Rein, from the University of California – Santa Cruz, concluded that grassland "... buffer strips are very effective for erosion control and sediment capture, both sediments and chemicals, and both historic and present." In addition, according to the Natural Resources Conservation service, conservation buffers slow water runoff, trap sediment, and enhance infiltration within the buffer. Buffer strips are also known to trap fertilizers, pesticides, pathogens, hydrocarbons, and heavy metals, and reduce blowing soil in areas with strong winds. Since it was determined that the restoration of a 500-foot wide wooded riparian corridor was not possible, resource specialists decided that adding a native grassland buffer component to the outside edges of the riparian corridor, where possible and practical, would help to improve the filtering of sediments and pollutants, including heavy metals, hydrocarbons, pesticides, fertilizers, pathogens, etc., improve the infiltration rate in the area, and help to buffer the wooded habitat from noise, and surrounding land use activities and human disturbance, thereby increasing the quality of the riparian habitat. The benefits of this grassland buffer are considered especially valuable in urban areas where there are multiple sources of point and non-point sources from runoff. Two different widths of native grass buffers, 50 feet and 100 feet, were retained as restoration measures –.

Grasslands – Grasslands and Tree Mottes Combination (Measure 6). According to Diggs et. al (1999), the presettlement condition of the Grand Prairie was largely a vast grassland, with woodlands found only as narrow ribbons of bottomland stands along the major watercourses, as scattered mottes in the prairie grasslands, or associated with draws and drainages of upland mesas and buttes. The addition of tree mottes with native grassland restoration would again mimic historic ecosystem conditions, while

incorporating an additional component of bottomland hardwoods to the floodplain. To further mimic natural conditions and not impede flood flow, these mottes would be established in random patterns, irregular in shape, relatively small, one-half to two acres in size, and be established in dense patterns to provide protective cover for hiding and reproduction. Hydrologic and hydraulic modeling indicates that the non-uniform scattering of tree mottes and/or planting narrow linear strips of bottomland hardwoods that run parallel to the river channel would be most efficient in helping to maintain flood conveyance in the study. This measure was retained for those areas where reforestation was precluded by the hydraulic constraints and no other restoration measures were specifically identified. A generic habitat gain and cost per acre were developed for this measure and utilized in its consideration during the incremental analyses.

Grasslands – Improvement of Native Prairie Grasslands (Measure 7). As was noted in the existing conditions descriptions in Chapter 2, the Tandy zone includes relics of the historic Fort Worth Prairie that once covered much of the region. The presence of this native prairie was indicated by the presence of little bluestem in composition with Indian grass, big bluestem, and switchgrass with small numbers of other common grasses and numerous species of forbs. The value of this prairie habitat is quickly deteriorating due to the invasion of woody species, such as eastern red cedar and mesquite, and erosion problems caused by human induced disturbances. Not only is the modification of this habitat type of grave concern to resource specialists because it is extremely rare (less than 1 percent of the native tallgrass prairies that were once found in Texas prior to settlement remain), but its value to wildlife and bird species is also being diminished, as is the diversity of the plant and animal species this prairie once supported. One of the measures being evaluated is the improvement of this native grass prairie by removal of the invading woody species that, if left unchecked, will eventually modify the prairie grasslands to low quality shrublands. Three alternative methods for doing this were considered by the study team – prescribed fire, mechanical removal, and hand removal. Prescribed burning was eliminated for safety reasons, because of the proximity of several residential structures to the prairie grasslands. Mechanical removal was also eliminated because of the fragile nature of thin soils and grassland vegetation, which is very susceptible to disturbances. Therefore, hand removal of the invading woody species was the restoration measure included in further analysis.

AQUATIC HABITAT. Restoration measures that would create and improve aquatic habitat in the study area would help to address several of the planning objectives, including restoring a more natural hydrologic regime; restoring and improving aquatic habitat for fish and other aquatic organisms; providing a sustainable level of food, nesting, and cover for all wildlife communities; restoring the stability, function, and dynamic processes of the floodplain to a more natural, less degraded condition; protecting and increasing habitat diversity and the interspersion of habitat types; and improving the water quality in conjunction with other ecosystem restoration activities.

Aquatic Habitat Improvements – Reconnect Oxbow to Flowing Water (Measure 8A1). There are numerous opportunities to restore aquatic habitat in the Riverside Oxbow study area. A major opportunity is to reconnect the oxbow to the modified channel and provide flowing water through the system. The oxbow has been physically disconnected from the river at both ends by construction of the flood diversion channel. The only water that enters the oxbow is from local runoff following rain events,

overbank flooding during flood events, or backwater from the West Fork that enters at the downstream confluence of the oxbow with the river channel. In typical summers, it isn't unusual for portions of the oxbow channel to be dry, particularly in the upstream end, which isn't often influenced by backwater from the West Fork. Other portions of the channel become shallow stagnant pools. Neither of these conditions is beneficial to the value of the aquatic habitat. Providing flow through the oxbow would serve to improve the aquatic habitat in the area because it would help reduce stagnation of water in the channel, improve dissolved oxygen levels and reduce the quantity of anaerobic sites, improve benthic habitat, provide inflow and outflow of nutrients and food sources, and help to lower the water temperature and provide a more consistent temperature regime.

In order to restore the hydraulic connection of the oxbow to the river (upstream end of the oxbow), the study team identified two means of opening flow between the oxbow and the modified channel. The options are to construct a culvert through the existing earthen plug or to remove the earthen plug altogether. These measures are shown in Figure 7. Either would allow water to flow from the modified channel into the oxbow, however, construction of the culvert would limit water flow to relatively low flow conditions, while the removal of the earth plug would allow for periodic flush flows during flood events on the West Fork. Accordingly, there are differences in the environmental benefits gained. Both measures are carried forward in the analysis.

In addition to the problem of how to reconnect the oxbow to the modified channel, there are other existing hydraulic problems in this reach that need to be addressed, both from an environmental standpoint and that of hydraulic feasibility. Opening only the upstream end of the oxbow to through flows is problematic. Additional problems include the downstream barrier at Beach Street and the need to provide some type of hydraulic control to avoid draining the water impounded in the modified channel. These additional problems are discussed below as measures 8A2 and 8A3, respectively.

Aquatic Habitat Improvements – Modifications at Beach Street (Measure 8A2). The Beach Street crossing of the oxbow channel consists of an earthen dam through which a culvert has been placed. This concrete culvert is approximately 12-feet in diameter and 245 feet long (see Figure 8). During current high water conditions, the culvert is inadequate to pass flows causing water to overtop the channel banks. This problem would be exacerbated once the upstream end of the oxbow is reconnected to the river. During low flow conditions, water stagnates in front of the culvert opening and does not flow into the culvert. This culvert also has a downstream invert that is higher than the existing ground surface elevations, resulting in water dropping several feet into the channel bottom during those occasions when water actually flows through the culvert. This hydraulic drop scours the channel and surrounding banks. Resource specialists noted that this scouring effect is destabilizing the bank along the roadbed of the turning lane for Gateway Park. In addition, during significant flow conditions, the drop pool becomes an eddy pool and, as water levels recede, debris is deposited along the banks at this site. The culvert also serves as a barrier to movement of species such as raccoons, opossum, rabbits, beaver, snakes, turtles, fish, and amphibians. Heavy traffic on Beach Street results in numerous road kills at the crossing. Figure 9 shows a lengthwise cross-section of the Beach Street culvert in relationship to the oxbow channel bottom.

The study team evaluated two measures for opening flows through Beach Street. One would be to replace the existing culvert with a box culvert that is set at a lower elevation at the same grade, which would help relieve the constriction and temporarily relieve the downstream scour. Over time it is anticipated that scouring would continue and debris would again collect. In addition, the length of the culvert would still serve as a barrier for movement of aquatic and terrestrial wildlife. The other measure evaluated was removal of the culvert at Beach Street to open the channel for flow and construction of a bridge that would span the channel, allow for planting of vegetation along the channel, and free movement of aquatic species in the channel and wildlife species along a riparian corridor between Oxbow North and Gateway Center and Gateway South. Both measures are carried forward for further analysis

Aquatic Habitat Improvements – In-channel weir (Measure 8A3). In addition to establishing a hydraulic connection to the river at both the upstream and downstream ends of the oxbow, implementation of some type of weir, or hydraulic control structure, is necessary to control the amount of water diverted from the modified channel into the oxbow during low flow conditions. This prevents potential adverse environmental impacts to the modified channel caused by draining the water impounded by the low water dam downstream of Beach Street (see Figure 9). The study team investigated and evaluated three locations for this weir. The first of these sites is at the upstream end of the oxbow channel where it meets the modified channel. The second location evaluated was at Beach Street. The final location evaluated for the in-channel weir was near a newly constructed pedestrian bridge just upstream of the confluence of the oxbow with the West Fork.

Besides providing hydraulic control, the location of an in-channel weir at either Beach Street or upstream of the confluence has the potential to provide additional aquatic habitat benefits, riparian terrestrial habitat benefits, and wetland habitat benefits by wetting a greater width and length of the oxbow during critical low flow periods. Diversion of water from the modified channel to the oxbow could provide flow of approximately 2 to 3 cubic feet per second during the 7-day 10-year low flow. This flow, while sufficient to reduce stagnation problems in the channel, is insufficient to wet the channel bottom perimeter. The hydraulic control would maintain the wetted perimeter necessary to maintain fisheries, benthic invertebrate production, and important habitat interface between the aquatic and terrestrial environment. On the negative side, the construction of an in-channel weir could impede the movement of aquatic species along the channel. The study team worked to design a structure that is friendly for aquatic species movement and is as natural looking as possible. Some of the design features include notched spillways across the top of the structure, which

Figure 7

Figure 8

Figure 9

will allow water flow under most conditions. The structure would also be designed to allow overtopping during high water conditions, which will allow the free movement of aquatic species at those times. Figure 8 shows a conceptual drawing of what the in-channel weir would look like upon implementation. All three siting options for the weir were carried forward for further analysis.

Aquatic Habitat Improvements - Boulder clusters (Measure 8B). By restoring flow through the oxbow, it is anticipated that the stream will once again take on many of the characteristics of a natural stream channel, more closely reflecting the historical aspect of the oxbow prior to the construction of the modified channel. This includes the formation of pools and riffles. Pools and riffles are associated with the thalweg, which will meander within the channel once flow is restored. Pools will typically form in the thalweg near the outside banks of bends and riffles in the straight portion of the channel where the thalweg crosses over from one side of the channel to the other. By opening the oxbow to flow, both periodic flood flows and low flow conditions, will, over time, remove the sediment build up within the oxbow channel that has collected since flows were cut off, and reestablish a natural riffle/pool complex. The addition of three series of boulder clusters placed in the base flow channel will help to provide cover and improve substrate, create scour holes, and areas of reduced velocities, all of which will add to habitat diversity, including spawning sites for fish species, shelter and structure for benthic invertebrates, improved habitat space and quality for aquatic invertebrates, and additional in-stream aeration. The careful placement of boulders clusters could also be used to protect the channel banks from erosion in potential problem sites. The exact locations of the boulder clusters would be determined after the oxbow is reconnected to the river and the channel has time to revert back to a natural riffle/pool system. The boulder cluster measure was retained for evaluation in combination with each measure to reconnect the oxbow to the river.

EROSION CONTROL (Measure 9). An additional problem identified is that of erosion and sediment transport, especially in the Tandy zone where the slopes are covered by a relatively thin layer of soil and vegetation that is easily damaged. Most of the erosion appears to be the result of illegal usage of the area by off road vehicles and random pedestrian hiking and biking trails, which have damaged the vegetation that helps to stabilize the slopes. In addition, the zone includes the site of a failed restaurant, which was once located on top of a hill between Tandy Hill Park to the east and the private residential lands to the west. The building has been removed, but considerable disturbance in the form of the slab, parking lots, and bulkheading remains. These areas of damaged vegetation provide locations for runoff following rain events. This runoff washes additional soil and vegetation from the slopes further exacerbating the problem and, over time, the soil on these slopes sloughs off and the problem magnifies. The existence of numerous riparian fingers with associated draws and rivlets in this zone that directly connect to the West Fork of the Trinity through a series of culverts under IH-30 mean that this soil quickly makes its way into the river causing increased sedimentation and turbidity and reducing the quality of the aquatic habitat. There are signs of major sediment deposition occurring in the river channel just downstream of one of the culvert outfalls connecting the Tandy zone to the West Fork of the Trinity River. The slope erosion also diminishes the terrestrial wildlife habitat value of the area. Bioengineering techniques and soft solutions are the preferred measure to stabilize the slopes, place topsoil, as needed, and

replant the areas with native grasses. This restoration measure was exclusive to the West portion of the Tandy zone and it was included in an interim analysis for the Tandy zone in combination with measures involving acquisition of the Tandy West property.

WOODLAND UNDERSTORY IMPROVEMENTS (Measure 10). The floodplain lands along the rivers and creeks and in the bottomlands of the study area are comprised of Frio soils, as are most of the floodplain lands in the Upper Trinity River Basin. Historically, the climax plant community for the Frio soil is mid- and tall-grasses with a tree canopy of pecan, elm, bur oak, and cottonwood. Currently, there is an invasion of non-native woody species, such as privet, occurring in the understory of the bottomland hardwoods in the Tandy zone. There are many wooded stands, especially on the eastern side of the Tandy zone, in the Tandy Hills parklands where the only native vegetation to be found is the canopy trees. Not only has this caused a loss of habitat quality and diversity within this zone, but the transportation of seed sources from the non-native invasive plant species in this area poses a significant threat to the other zones within the study area and to the terrestrial and aquatic habitat of the lands along the West Fork downstream of the Tandy zone. This restoration measure was exclusive to the East portion of the Tandy zone and it has been included in an interim analysis for the Tandy zone in combination with acquisition of the Tandy East property.

FENCING (Measure 11). As was described in the Erosion Control section above, most of the erosion occurring in the Tandy zone appears to be the result of illegal use of the area by off road vehicles and random pedestrian hiking and biking trails which have damaged the vegetation that helps to stabilize the slopes. One of the restoration measures evaluated by the study team for the Tandy zone includes limiting assess to the zone by fencing the boundaries using a post and cable fencing system. This restoration measure was exclusive to the Tandy zone. It has been included in an interim analysis in combination with acquisition of Tandy zone property of any scale.

SUMMARY – ECOSYSTEM MEASURES AND SCALES

The section has described the restoration measures and scales developed by the study team to improve habitat values within the study area. A relatively large number of measures and scales were identified. For clarity purposes, Table 8 displays a list of all the restoration measures identified for the study area and gives the number of the page, or pages, where the measure is discussed in more detail.

RESTORATION MEASURES BY ZONE

Plan formulation was undertaken to address identified problems by project zone, starting in the oxbow area. Most of the Riverside Oxbow study area is within the 100-year floodplain of the West Fork of the Trinity River and contains similar assemblages of vegetative habitat types. Formulation and evaluation of measures by habitat type in the oxbow zones (North, Center, and South) were therefore applied to similar habitat types in the Gateway zones (Center, South, Beach, Park, and East).

The following paragraphs describe the formulation and evaluation of restoration measures and/or scales of measures for each of the zones within the study area to meet the planning objectives, relative to the "without project" condition. As noted earlier in this chapter, real estate costs have been incorporated into the annualized costs of restoration measures, except for the Tandy zone where the study team evaluated several different acquisition sizes. All other measures identified in Table 8 were applied, as applicable, to the problems identified for each of the study zones.

Oxbow North. The Oxbow North zone includes the cutoff oxbow channel between Riverside Drive and Beach Street, which is approximately 1.3 miles in length, its associated riparian corridor, an adjacent ponded area just upstream of Beach Street, the lands around the ponded area, and a small parcel of land between Riverside Drive and the upstream end of the cutoff channel.

During existing conditions investigations, several problems specific to the quality of the habitat were noted within the Oxbow North zone. These include: 1) the narrow width of the wooded corridor; 2) gaps within and between wooded tracts; 3) a lack of hard- and soft-mast producing trees and shrubs; 4) a lack of cavity trees in the existing wooded tracts for brood rearing and nesting; 5) understory vegetation in some tracts that is too dense or comprised of non-native vegetation species; 6) the lack of water flow through the oxbow which results in an alternate series of stagnant pools and areas of dry channel; 7) adjacent land use activities to the north that could adversely impact water quality parameters in the oxbow and the quality of the riparian corridor habitat; and 8) a culvert at Beach Street, which functions improperly during both high and low flow conditions and which blocks the safe migration of wildlife species along the riparian corridor and aquatic species within the channel.

An additional constraint identified in this area is a site north of the oxbow that has been contaminated by hydrocarbons. This site was brought to the attention of the Fort Worth Environmental Department because of the discovery of hydrocarbon contamination in the soil during the installation of a sewerage line about three years ago. At that time, actions were taken to avoid the contamination during the construction of the sewer line and the project was completed. The site was not remediated and the hydrocarbons remain in the soil. The city's Environmental Department provided the study team with a map of the area delineating the extent of contamination, but questions remain as to the extent of the contamination. Rather than incur the costs associated with a costly and lengthy HTRW investigation and remediation effort at this time, it was determined that the site and surrounding lands would be removed from further consideration for restoration efforts as project lands. Reduction in study area size by 6 acres in this zone ensures that the site is avoided and provides a conservative buffer around the site to protect against potential future impacts to project lands.

Oxbow Center. This zone is bordered on the west and north by the Oxbow North zone, on the east by Beach Street, and on the south by the modified channel. Approximately 124 acres in size, this zone is predominately grasslands. A partial remnant channel of Sycamore Creek holds local runoff for short periods of time each year providing a small seasonal wetland. There are several large individual pecan and bur oak trees scattered along the edges of the abandoned Sycamore Creek channel in this zone.

During existing conditions investigations, problems specific to the quality of the habitat within the Oxbow Center zone were identified. These include: 1) the lack of bottomland hardwoods, with the exception of the few scattered pecans and oaks; 2) the relatively poor quality of the grassland habitat, which is comprised mostly of coastal Bermuda and Johnson grass; 3) the ephemeral nature of the existing small wetland which has little habitat value; and 4) the existence of several acres of disturbed soils which have no habitat value.

Another constraint to potential restoration opportunities in the zone is the location of site identified by the city of Fort Worth for future development of an outdoor soccer facility. The site in question is located in the north central region of the zone. Because the location of the facility would not adversely impact the creation of the wetland complex and the proponent for the facility expressed their willingness to meet certain guidelines for such items as directional lighting; the limited use of fertilizers, herbicides, and pesticides; the design and specification of fencing materials; and the operations and maintenance of the facility; it was determined that construction and operations of the soccer complex would not adversely impact the value of the surrounding habitat. For this reason, the site has been removed from further consideration for restoration efforts or inclusion in the project study area. The removal of this site from the Oxbow Center study area reduces the acreage in the zone to 85.1 acres and reduces the existing wildlife habitat value to 54.4 habitat units.

A final constraint to restoration opportunities in this area is the finding of a buried cultural site near where Sycamore Creek once confluence with the original West Fork channel. The location of the small outlet channel from the wetland complex to the oxbow channel needs to be configured to avoid adverse impacts to a prehistoric cultural resources site.

Table 8
Ecosystem Restoration Measures and Scales Evaluated

#	Measures	Scales	Comments
	Acquisition	Incorporated in restoration costs.	p. 66
1	Reforestation of bottomland hardwoods		
		A - Extent	Capped at 10 percent; see pp. 67-68
		B – Corridor width	100 meters; see p. 69
		C – Density and planting materials	40 1-inch caliper containerized trees, 20 1-gallon containerized shrubs and 150 seedlings per acre; see ICA pp. 69-71
2	Improvements to existing bottomland hardwoods	Density	5 1-inch containerized trees, 5 1-gallon containerized shrubs, and forest management (thinning, etc.) per acre pp. 70-71
3	Creation of wetland complexes		
		A – Size	5.1-, 12.3-, or 17.8 acres in Oxbow Center; pp. 66-67 and 15.0-, 26.8-, or 35.0 acres in Gateway East, p. 72-73
		B – Wetlands plus water	p. 73

		control and wetland plantings	
		C – Wetlands with water control and wetland plantings plus water supply	Permanent pumping station; pp. 74-75
4	Improvements to existing wetlands		
		A – Recontouring	p. 74
		B – Recontouring plus water control and plantings	p. 75
		C – Recontouring with water control and plantings plus water supply	p. 75

Table 8, continued.

#	Measures	Scales	Comments
		D – Recontouring with water control, plantings, and water supply plus removal of old Gateway Park road	pp. 75-76
		E – Adding water control structure	p. 76
5	Grassland buffer strip along riparian corridor		
		Size	50 or 100 meters in width; p. 77
6	Grasslands and tree motte combination	Yes/No	p. 77
7	Restoration of native prairie grasslands	Yes/No	p. 78
8	Aquatic habitat improvements		
		A 1 – Reconnect - upstream	
			Culvert; p 79
			Remove plug; p. 79
		A 2 – Reconnect - downstream	
			Replace culvert with box culvert; p. 79
			Replace culvert with bridge; p. 79
		A 3 – In-channel weir	
			Located at upstream end of oxbow; p. 80
			Located near Beach Street; p. 80
			Located near downstream confluence of oxbow and the West Fork; p. 80
		B – Boulder clusters	p. 80
9	Erosion Control		
			Repair slope, add topsoil, and plant native vegetation; pp. 80-81
			Remove slab and parking, repair slope, add topsoil, and plant native vegetation; pp. 80-81
10	Woodland understory improvements	Yes/No	p. 81
11	Fencing	Yes/No	p. 81

Oxbow South. The Oxbow South zone includes the area along the south and east banks of Sycamore Creek between IH-30 and the channel and a broader area between the modified channel and IH-30 extending from the west bank of Sycamore Creek to Riverside Drive. A parcel of land just west of Beach Street was not included in the study area within this zone because of the presence of a church. This zone also includes the confluence of Sycamore Creek with the modified channel, a low water dam downstream of Beach Street, and an existing 3.1-acre wetland.

During existing conditions investigations problems specific to the quality of the habitat within the Oxbow South zone were noted. These include: 1) the lack of bottomland hardwood stands limit this site's value to native and migratory wildlife and avian species; 2) the relatively poor quality of the grassland habitat, which is comprised mostly of Bermuda grass and Johnson grass; and 3) the noise from the adjacent IH-30.

Besides the constraints established by the CDC and ROD criteria for the overall Riverside Oxbow study area, which helped determine what types of restoration options are viable in this zone, two other constraints have an impact on the restoration opportunities in the Oxbow South zone. Representatives of the Tarrant Regional Water District advised the study team that there was a verbal commitment between TRWD and the congregation of the church that occupies a parcel of land just west of Beach Street adjacent to the Oxbow South zone. The agreement was for TRWD to allow the church to use lands owned by TRWD located west of the church to 50 feet east of Sycamore Creek in exchange for the church giving TRWD control of a 50 foot wide swath of land owned by the church from the top of the bank on the south side of the modified channel. The church has expressed its intention of using the land currently under TRWD ownership for a baseball and softball field and recreation area. The study team therefore determined that these lands would no longer be available for restoration and they would be removed from potential project lands, leaving 28.7 acres available for restoration.

Gateway Center. This reach is located in the area immediately downstream of the Beach Street crossings of the modified channel and the remnant oxbow channel. It is a triangular-shaped tract of land that contains low quality woodlands, highly manicured grasslands, and about 7.6 acres of disturbed lands. The location of the zone provides an important link between upstream resources and those associated with the riparian forest located downstream. Ecosystem restoration efforts in this zone have the potential to be not only highly beneficial to this site, but, as an integral link, could provide positive cumulative benefits to the upstream and downstream reaches.

During existing conditions investigations, resource specialists noted problems specific to the quality of the habitat within the Gateway Center zone. These include: 1) the lack a contiguous riparian corridor along the south side of the oxbow; 2) the low quality of the existing bottomland hardwood stands; 3) the low quality of the maintained grasslands; 4) the abundance of disturbed lands which supply no habitat value; and 5) the location of a rundown wooden pallet manufacturing facility located in a small parcel of land along Beach Street which serves as an eyesore in the area and has adverse impacts on the habitat value of surrounding resources.

Gateway South. This study zone encompasses the Gateway Center zone to the north and south across both the oxbow channel and the modified channel. North of the oxbow, the zone generally includes the bottomland hardwood corridor located between Beach Street on the west, the park entrance road to Gateway Park on the north, and the first river bend below the confluence of the oxbow with the West Fork on the east. South of the modified channel the zone includes mostly grasslands from Beach Street on the west, the modified channel on the north, IH-30 on the south, and the first river bend below the confluence of the oxbow with the West Fork on the east. Much like the Gateway Center zone, this zone has linkages to all components of the oxbow and all components of Gateway Park. Ecosystem restoration efforts in this zone, as an integral link, could provide positive cumulative benefits to the upstream and downstream zones.

Problems noted specific to the quality of the habitat within the Gateway South zone include: 1) gaps within the riparian corridor along the north side of the oxbow; 2) a lack of hard- and soft-mast producing trees and shrubs in existing wooded tracts; 3) a lack of cavities trees in the existing wooded tracts for brood rearing and nesting; 4) understory vegetation in some tracts that is too dense or comprised of non-native vegetation species; 4) the low quality of the maintained grasslands; and 5) traffic noise from IH-30.

In addition to the CDC constraints, this zone has been identified for channel and overbank modifications to mitigate for the rise in surface water profiles as a result of planting additional bottomland hardwood forest stands in the 100-year floodplain in other project zones. Mitigation efforts would require the removal of approximately 100,000 cubic yards of material along the south bank of the channel and in the overbank area in this zone. It was determined that the river bank downstream of the low water dam would be cut back up to 50 feet and the top of bank graded to resemble a natural overbank terrace. Material would be cut out behind the terrace in the existing grasslands to simulate a wet meadow restoration. USFWS and TPWD concur that this area of hydraulic mitigation currently provides no environmental value and does not require environmental mitigation. Conceptual plans for this design are included in the Civil Design appendix of the feasibility report. The final design details would be undertaken during plans and specifications of the project once all the restoration designs and specifications are completed and a final hydrologic model developed for projected project conditions.

Gateway Beach. This zone includes approximately 160 acres of land east of Beach Street, north of the entrance road to Gateway Park off of Beach Street, and east to Gateway Park. The area, which has been heavily disturbed by past activities, is generally grasslands (mostly bermudagrass), which provides low quality habitat, with a component of low quality woody vegetation located around some existing ponds and wetlands, and approximately 47 acres of disturbed soils, as a result of fill activities.

Specific problems related to the quality of the habitat within the Gateway Beach zone include: 1) large acreage of disturbed land with no habitat value; 2) low quality of the existing grasslands which make up the large portion of the zone; 3) the low quality of the aquatic habitat in existing ponds and wetlands; 4) the proliferation of non-native shrubs around the higher banks of the largest wetland which greatly reduces wildlife habitat values; 5) a lack of hard and soft mast producing trees and shrubs in the existing forested habitat around the wetlands; 6) a lack of snags and cavities for use as brood rearing and nesting sites; 7) a lack of a reliable water source for the wetlands areas; 8) the lack of

contours and terraces in the existing wetlands that limit the quality and quantity of wetland habitat; 9) the location of the park entrance road off of Beach Street which serves as a barrier to a natural hydraulic connection between the wetlands in the zone and the oxbow to the south; and 10) Fort Worth's Recreation Master Plan for the existing and potential future lands within and adjacent to Gateway Park which identifies some portions of the zone for future intensive recreation development actions.

The constraints identified in this zone, in addition to the CDC criteria, are other Section 404 permitted activities and their associated hydraulic and hydrologic mitigation requirements. Originally, gravel and soil mining activities in the area resulted in the creation of several ponds and wetlands. Some of these wetlands and ponds were subsequently filled under Section 404 permit conditions issued in November 1987. In addition to filling some of the ponds and wetlands, the ground elevation in a portion of the zone was raised out of the 100-year floodplain by these fill activities. Gravel and soil mining activities resulted in the creation of several ponds and wetlands, some of which were subsequently filled under Section 404 permit conditions issued in November 1987. The filled portion of the zone has largely reestablished a grass cover; however, Bermuda grass, which provides low quality habitat conditions, dominates. Although no pads or buildings have been constructed on the fill, future without project conditions indicate that little additional filling would be required to make the portion of the tract that fronts Beach Street a highly desirable location for commercial development. As mitigation for fill activities, a small wetland area was contoured to connect to one of the residual lakes and a little bank sloping was conducted to foster some moist soil development. These areas provided adequate mitigation for the past filling activities; however, substantial improvements could still be implemented to provide substantially greater fish and wildlife habitat benefits.

Finally, representatives of the Fort Worth Parks and Community Services Department provided the study team with a map delineating the location of future recreation development activities as identified in their recently completed and approved Gateway Park Recreation Master Plan. The Master Plan and map depicts planned future recreation development on existing and potential future lands within and adjacent to Gateway Park. According to the master plan, some of the lands located in the Gateway Beach zone along East 1st Street are slated for future recreation development. Based on this, the study team decided to remove these lands, roughly 22 acres, from further consideration for restoration efforts.

Gateway Park. This zone includes all the lands south of East 1st Street between Gateway Beach and Gateway East. The majority of these lands, approximately 120 acres, are maintained grasslands with about 68.6 acres of woodlands and 68.4 acres of disturbed areas. The disturbed areas include the old wastewater treatment facility, existing softball fields and associated parking lots, and park access roads.

Currently, most of the lands within this zone are either being utilized for intensive recreation activities, i.e. soccer fields, softball fields, rugby fields, etc., or are slated for future use as intensive recreational activity sites. The exception to this is the parcel of land and the facilities associated with the old wastewater treatment plant. At this time, the city of Fort Worth is not interested in pursuing the demolition and removal of the structures in this area and analysis and probable clean up of this site to make it usable for recreation

or restoration purposes. Given the current and proposed future usage of the lands within this zone for intensive recreational activities, the study team determined that the lands within this zone should be removed from further consideration for ecosystem restoration opportunities.

Gateway East. This study reach extends downstream of the Gateway Center and east of the Gateway Park zone to the East 1st Street bridge. The zone contains about 139 acres of lands, consisting of 97.01 acres of riparian forest, 0.72 acres of water, 5.62 acres of wetlands, and 34.94 acres of grassland. Only 0.43 acres of disturbed soil was identified.

Problems specific to Gateway East zone include: 1) areas with a narrow riparian corridor, especially in the western portion of the zone; 2) a lack of hard- and soft-mast producing trees and shrubs in some of the existing wooded tracts; 3) a lack of cavities trees in the existing wooded tracts for brood rearing and nesting; 4) understory vegetation in some tracts that is too dense or comprised of non-native vegetation species in some areas; 5) areas disturbed by past use as drying beds in waste water treatment processing; and 6) an old oxbow remnant of the West Fork no longer connected to the river channel except during periods of high flows.

There are two constraints applicable within this zone, the CDC constraints and contamination of sediment in the drying beds of the abandoned wastewater treatment plant. As noted previously, the CDC constraints have been accommodated in the definition/development of the reforestation measures. The city of Fort Worth has indicated that they are working with the Texas Commission on Environmental Quality to develop a clean closure plan for the drying beds and will take responsibility for cleaning up the site prior to the lands being acquired for inclusion in the proposed ecosystem restoration project. The USFWS is reviewing the city's site report and will monitor clean up activities to ensure that there is no potential to adversely impact wildlife and avian usage of the area in the future.

Tandy. The Tandy zone contains about 160 acres of mixed grassland, shrubland, and trees over a highly diverse terrain. Vegetation analysis identified roughly 60 acres of woodlands, 90 acres of grasslands, and at least 8 acres of disturbed lands; however, it is believed that the amount of disturbed soils have more than doubled since the date the imagery was captured. Less than one acre of moist soils associated with the many small rivlets originating on the hillsides was identified. The entire site is unique within the area due to the diverse topography and the presence of a relic native prairie that is slowly being modified due to human disturbances and changes brought about due to control of wildfire that historically helped maintain prairie areas.

Problems specific to the Tandy zone include: 1) invasion of the grasslands from eastern red cedar, mesquite, and other woody species which is degrading the value of the prairie habitat; 2) proliferation of non-native species, such as privets, invading the understory of the wooded riparian stringers, especially in the Tandy Hills Park portion of the zone; 3) erosion problems on the slopes which are contributing to sedimentation and water quality problems and reducing aquatic habitat in the West Fork river channel downstream of the outfalls from the Tandy zone; 4) disturbance from a failed restaurant including the remnant foundation slab, parking lot, and slope bulkheading; 5) trash dumping and illegal off-road vehicle usage of the area, which adversely impacts the vegetation and causes

erosion; 6) transportation of light seeds from invader species vegetation in this zone poises a significant threat to the entire study area and areas downstream along the West Fork of the Trinity; and 7) the loss of habitat and species diversity and population numbers as a result of human-induced modifications to the vegetation composition.

As noted in the existing conditions discussion of the Tandy zone in Chapter 2, the construction of IH-30 on a raised bed serves as an impediment to the physical and natural ecosystem connections between the Tandy zone and the river channel and other zones within the study area, but has not severed the interconnectedness of the zone from the riparian corridor. Site reconnaissance during the existing conditions investigations have shown that the highway has not stopped adverse impacts to the river channel from increased sediment loading as a result of slope erosion in the Tandy zone. In addition, the highway doesn't serve as a barrier to avian species that are known to utilize both the Tandy zone and the riparian corridor in the other zones. The transport of seed sources from light-seeded non-native vegetation from the Tandy zone is occurring as a result of the prevailing winds, bird droppings, and runoff following rain events. The proximity of the Tandy zone to the other zones in the study area makes it even more important to remove the source of non-native vegetative species which unless controlled would ultimately result in increased operation and maintenance costs of the other areas of project.

Benefits that could be obtained from restoration of this zone would predominantly occur on lands outside the 100-year floodplain, which traditionally has not been a high priority for USACE restoration efforts; however, the proximity of the site and the potential for degradation of the site to have adverse impacts on the higher priority resources associated with the West Fork of the Trinity River should be considered.

As part of the plan formulation and evaluation process, all benefits and adverse contributions of applicable restoration measures and scales, were compared to existing conditions, as described and summarized in Chapter 2, and future without project conditions.

Less than half of the lands within the study area are owned by public or quasi-public entities. While a majority of the lands within the study area might be protected from development due to their location within the 100-year floodplain, the management of the lands, even those in public ownership, leaves them vulnerable to uses that are not compatible with quality wildlife habitat.

Various tracts of land between the oxbow and the modified channel have multiple owners. Until a few years ago, a majority of the land was leased for hay production. Now it is maintained by the TRWD who generally mow it several times a year. During site reconnaissance in the summer of 2001, fill activities were observed in the remnant scar of the old Sycamore Creek channel located in the Oxbow Center zone. Since construction of the modified channel, this low lying area has been a shallow, ephemeral wetland, whose sole water source is localized runoff and periodic overbank flooding along the river channel. Because it is typically dry for so much of the year, this wetland has little value as wetland habitat, but even that value would be lost through further fill activities.

It is anticipated that much of the riparian habitat still existing along the northern edge of the old oxbow would be cleared in the future to accommodate storage and stockpiling

activities associated with the various commercial and industrial uses in which the owners are engaged. The private lands along the east side of Beach Street would likely be developed for commercial businesses. Other lands within Gateway Park itself and already owned by the city of Fort Worth, would be vulnerable to future active recreation uses that would virtually eliminate any of their value for wildlife habitat. Even the habitat value of the lands located within the Tandy Hills area, whose topography generally renders it inviolate to development, would decrease in the future as the lands are further damaged by off road vehicle use and invasion of exotic plant and tree species.

MEASURES CONSIDERED BY ZONE

The previous narrative described the restoration measures and scales applied to various zones in the study area. Some of the restoration measures are utilized in more than one zone and some of the measures impact more than one zone. Tables 9 displays the zones where the restoration measures were considered for implementation and any other zones that would be directly affected. Table 9a displays the restoration measures that were considered for each zone in the subsequent Incremental Analysis and Cost Effectiveness analysis.

Table 9
Zones Considered and Zones Affected by Restoration Measures

Measure #s	Zones Considered	Zones Affected
1	OXN, OXS, GWC, GWS, GWE	OXN, OXS, GWC, GWS, GWE
2	OXN, OXS, GWC, GWS, GWE	OXN, OXS, GWC, GWS, GWE
3	OXC, GWE	OXC, GWE
4	GWB, OXN, GWE	GWB, OXN, GWE
5	OXN, OXS, GWC, GWS, GWE	OXN, OXS, GWC, GWS, GWE
6	OXN, OXC, OXS, GWC, GWS, GWB	OXN, OXC, OXS, GWC, GWS, GWB
7	TD	TD
8	OXN, GWC	OXN, GWC, GWS
9	TD	TD
10	TD	TD
11	TD	TD

OXN – Oxbow North, OXC – Oxbow Center, OXS – Oxbow South, GWC – Gateway Center, GWS – Gateway South, GWB – Gateway Beach, GWE – Gateway East, TD – Tandy.

.

Table 9a
Restoration Measures considered by Zone

Zone	Measures Applied
Oxbow North	1, 2, 4, 5, 6, 8
Oxbow Center	3, 6
Oxbow South	1, 2, 5, 6
Gateway Center	1, 2, 5, 6, 8
Gateway South	1, 2, 5, 6
Gateway Beach	3, 6
Gateway East	1, 2, 3, 4, 5
Tandy Hills	7, 9, 10, 11

1 – Bottomland Hardwood Reforestation, 2 – Bottomland Hardwood Management, 3 – Creation of Wetlands 4 – Improvement of Wetlands, 5 – Grassland Buffer Strips, 6 – Grassland/Tree Mottes, 7 – Native Prairie Restoration, 8 – Aquatic Habitat Improvement, 9 – Erosion Control, 10 – Wooded Understory Improvements, 11 – Fencing

The USFWS Habitat Evaluation Procedures (HEP) were used to quantify the habitat values within each study area zone under existing conditions and for each ecosystem restoration measure applied to each zone as summarized in Tables 9 and 9a of this chapter. The Habitat Unit outputs, along with the costs of the various measures were input to the IWRPlan model, which generates incremental analysis and cost effectiveness outputs for each measure for each zone. The output data from IWRPlan are included in this report as an Addendum to Appendix E. Rather than displaying the HEP data for all measures for all zones, an example for habitat type is presented below.

EXAMPLE SUMMARY OF INCREMENTAL ANALYSIS STEPS FOR OXBOW CENTER.

Under existing project conditions, the acreage in Gateway South was 138.72 acres. Table 10 displays acres, existing conditions HSI value, , and the computed number of habitat units of each habitat type in the zone under existing conditions.

Table 10
Gateway East Summary of Habitat Units – Existing Conditions

Water		Wetlands		Forest		Grassland		Disturbed	
Acres	HSI	Acres	HSI	Acres	HSI	Acres	HSI	Acres	HSI
0.72	0.4	5.62	0.38	0.97.01	0.64	34.94	0.13	0.43	0
HUs – .29		HUs – 2.13		HUs – 62.09		HUs – 4.54		HUs – 0	

Therefore, the total number of habitat units for the zone under existing conditions equals 69.05.

The next step is to annualize the habitat units for the future without and future with project, or with measure, conditions over the 50 years life of the project.. The future with project conditions are calculated separately for each of the restoration measures considered for the zone. Table 11 displays the results of the annualization for future without project conditions for each restoration measure considered in the zone.

Table 11
Habitat Unit Annualization Summary for Oxbow Center

Measure	TYO (Current) HUs	Year 1 HUs	Year 10 HUs	Year 50 HUs	Average Annual HUs
Future Without Project	69.05	68	65	60	63.48
Contour 15 ac wetland	0 (15 * 0.0)	3 (15*0.2)	4.5 (15*0.3)	5.25 (15*0.35)	4.51
Contour 26.8 ac wetland	0 (26.8*0.0)	5.36 (26.8*0.2)	8.04 (26.8*0.3)	9.38 (26.8*0.35)	8.07
Contour 35 ac wetland	0 (35*0.0)	7 (35*0.2)	10.5 (35*0.3)	12.25 (35*0.35)	10.53
Contour 15 ac wetland + plantings & water control	0 (15*0.0)	6 (15*0.4)	9 (15*0.6)	9 (15*0.6)	8.44
Contour 26.8 ac wetland + plantings & water control	0 (26.8*0.0)	12.06 (26.8*0.45)	17.42 (26.8*0.65)	18.22 (26.8*0.68)	16.70
Contour 35 ac wetland + plantings & water control	0 (35*0.0)	14 (35*0.40)	22.75 (35*0.65)	23.8 (35*0.68)	21.63
Contour 15 ac wetland + plantings, water control, & water source	0 (15*0.0)	6.75 (15*0.45)	10.2 (15*0.7)	11.7 (15*0.75)	10.15
Contour 26.8 ac wetland + plantings, water control, & water source	0 (26.8*0.0)	13.4 (26.8*0.5)	25.46 (26.8*0.95)	26.26 (26.8*0.98)	23.84
Contour 35 ac wetland + plantings, water control, & water source	0 (35*0.0)	17.5 (35*0.5)	33.25 (35*0.95)	34.3 (35*0.98)	31.14
Water control for u-shaped wetland	4.8 (12.5*0.38)	6 (12.5*0.48)	9.6 (12.5*0.77)	10.8 (12.5*0.86)	9.58
Reforestation (7 ac), habitat improvement (97.1 ac), native grass buffer (3.8 ac),	63.17	42.15	73.77	89.57	76.55

Once the annualization of habitat units is complete, the final component to be incorporated into the cost effectiveness and incremental analysis is the annualized first costs of the restoration measure, including operation and maintenance costs. Table 12 displays the annualized first costs of all the restoration features in Gateway East.

Table 12
Annualized First Costs for Measures in Gateway East

Measures	Annualize First Costs
Contour 15 ac wetland	$22,445
Contour 26.8 ac wetland	$39,422
Contour 35 ac wetland	$57,803
Contour 15 ac wetland + plants & water control	$27,876
Contour 26.8 ac wetland + plants & water control	$45,350
Contour 35 ac wetland + plants & water control	$64,677
Contour 15 ac wetland + plants, water control & water source	$29,721
Contour 26.8 ac wetland + plants, water control & water source	$47,272
Contour 35 ac wetland + plants, water control & water source	$66,523
Restoration of native grass buffer (3.8 ac)	$1,840
Restoration of native grass/mottes (4.02 ac)	$1,355
Reforestation of 7 ac and habitat improvement of 97.1 ac	$13,213

As was noted earlier in this chapter, an interim incremental analysis was conducted to determine the size of the wetland complex to be implemented in the Gateway East zone. The 26.8-acre wetland complex with water control, plantings, and water source was selected as the plan of choice. In the final incremental analysis, the average annual habitat units gained incrementally as a result of implementation of this wetland cell (23.84 AAHUs) was added to 76.55 AAHUs gained from restoring 3.8 acres of native grass buffer, 4.02 acres of native grass/tree mottes combination, 97.1 acres of habitat improvement, and 7 acres of reforestation and the 9.58 AAHUs gained by adding water control to the u-shaped wetlands. The total number of AAHUs for the Gateway East zone in the overall analysis was, therefore, 109.97 AAHUs.

The total annualized costs input into the overall analysis for the zone included $47, 272 for the wetland complex, $13,213 for the reforestation and habitat improvement, $1,840 for native grass buffer, $1,355 restoration of native grass/mottes plus the annualized costs of the real estate acquisition, $40,783. Tthe final annualized first costs for the restoration measures proposed for Gateway East totaled $104,463.

The incremental analysis and cost effectiveness calculations within IWRPlan then compare the full scenario of first added to last added measures of the various zones to identify the array of "best buy" plans displayed on Table xx.

TANDY CONSIDERATIONS

Results of the interim analysis of Tandy measures are shown in Table 13, which summarizes the "best buy" combination plan components, the average annual habitat units (AAHUs), the incremental AAHUs, annualized costs, the average annual cost per AAHU, and increment cost per output. The analysis identified 512 possible combinations, 19 considered to be cost effective, and three "best buy" combinations besides the "no action" plan. All the "best buy" combinations for the Tandy zone were included in the final overall analyses

Table 13
Best Buy Plan Combinations for Tandy
Acquisition and Restoration

Plans	AAHU	Incremental AAHUs	Annualized Costs	Incremental Annualized Costs	Average Cost Per AAHU	Incremental Cost Per Output
Acquire Tandy East, invasion control in grasslands & understory, & fencing	71.44	71.44	$184,743	$184,743	$2,585.99	$2,585.99
Acquire Tandy East and West, invasion control in grasslands & understory, fencing, & erosion control	113.56	42.12	$328,031	$143,288	$2,888.61	$3,401.90
Acquire Tandy All, invasion control in grasslands & understory, fencing, erosion control, remove slab & parking & restore	127.00	13.44	$384,066	$56,035	$3,024.14	$4,169.27

EVALUATION OF ALL ALTERNATIVES

PREDICTION OF ENVIRONMENTAL OUTPUTS. Various methods were utilized in the plan formulation phase to help compare and evaluate the existing, future with-, and future without project conditions, including vegetation imagery and HEP. Habitat Suitability Index (HIS) models specific for wildlife and bird species known to utilize the representative habitat types, i.e. grasslands, riparian/bottomland hardwood sites, and wetlands, were used in the HEP analyses. Using HSI values developed during the existing conditions phase of the study for each major habitat type in each zone, habitat units (HUs) were computed by multiplying the HSI values for each of the three important vegetative covers types and open water within each zone by the number of acres of that habitat type within that zone. The final cover type identified by the vegetation classification process was disturbed soils, which were considered to have zero habitat value for these analyses. The habitat units were then averaged and annualized over the life span of a project to derive the average annualized habitat units (AAHUs). In this case, the project life was set for 50 years, based on guidance found in Engineering Regulation (ER) 1105-2-100, Planning and Policy Guidance for Conducting Civil Works Planning Studies. The use of 50 years as the project life does not allow credit for the maximum habitat value of the riparian/bottomland hardwood habitat type since it takes many of the hard mast producing bottomland hardwood trees (e.g. oaks, pecans, etc.) up to 75 years or more to reach their full maturity. Restoration opportunities were evaluated by comparing the baseline AAHUs with projected AAHUs given implementation of a proposed restoration measure or scale within each zone or across the entire project area, as applicable. Projections of the HSI values and the derived future with- and without project AAHUs are based on the professional judgment of resource specialists, including those from USACE, USFWS, and TPWD.

There was no HEP modeling done on the aquatic habitat in the oxbow. At the time of the field surveys, resource specialists, using their professional judgment, decided the value was zero within the oxbow itself, since a majority of the old oxbow channel was either dry or stagnant pools. The majority of the habitat benefits derived for improving the aquatic habitat in the oxbow (reconnecting to the river) were measured in terms of improvements to the adjacent riparian corridor and to the shallow vegetated wetlands that are anticipated to develop along the fringes of the oxbow channel once flow is restored. Even though resource specialists feel that reconnection of the oxbow at both the upstream and downstream end will improve the aquatic habitat in the modified channel and the West Fork downstream of the confluence due to the fact that reconnection will allow migration of aquatic organisms and fish into the oxbow for food, cover, and reproduction purposes and then back out into the main channel, there was no attempt made to quantify or include these benefits into the evaluation of project features. An analysis was conducted however during the plan formulation process to maximize aquatic habitat diversity attributable to the oxbow restoration measures. It was determined that a general water surface elevation of 493 feet msl would provide pools up to six feet in depth a thalweg depth varying from 4- to 6-feet and an average cross sectional average depth of less than four feet. Decreasing the water surface elevation increases the length of channel that would have to be deepened near the upstream diversion to maintain flow. Increasing the elevation produces little additional wetted perimeter aquatic habitat and produces a greater volume of water with decreased turnover rate thereby decreasing the stream characteristics desired for the oxbow restoration.

Table 11 shows the existing conditions habitat units for each vegetation type and open water by project zone along with the future without project average annualized habitat units and acres.

COST EFFECTIVENESS AND INCREMENTAL ANALYSIS. In cost effectiveness and incremental analysis (CE/IA) models, a "no action" measure was developed for each of the separate measures identified. Next average annualized habitat unit gains for each measure and/or scale and their "no action" counterparts were computed over a 50-year period. In addition, annualized costs, including real estate and operations and maintenance costs, were computed for each of the measures. This data was then input into a comparative analysis model. The model used to run cost effectiveness and incremental cost analysis was the IWR-Plan: Decision Support Software, Version 3.3. The final analysis identifies a list of "best buy" plans, which represent the most cost effective plans in terms of costs per habitat units gained. Interim cost effectiveness and incremental analysis were run for 9 alternative combinations for created wetland complexes in both Oxbow Center and in Gateway East. In each case, the study team determined that the medium-sized wetland complexes, 12.3 and 26.8 acres, respectively, along with the addition of quality wetland plants, water control structures that would allow manipulation of water levels to optimize for habitat values during different seasons, and a permanent water supply to be used when necessary to ensure the function and quality of the wetland complex over time, were the "best buy" plans of choice. The AAHUs and annualized costs for each of the selected created wetland complex "best buy" plans for Oxbow Center and Gateway East were added to the AAHUs and annualized costs for the other restoration measures identified for that respective zone and included in final overall analyses.

In addition, interim cost effectiveness and incremental analysis were run for 113 different combinations of land acquisition and restoration measures identified for the Tandy zone. The "best buy" plan combinations identified by the interim analyses for Tandy were shown in Table 12. All three "best buy" combinations were carried forward into the final analysis. The results of the interim and overall cost effectiveness and incremental analyses are included as an addendum to the Environmental Appendix (Appendix E) in this report. This addendum also includes the existing conditions vegetation analysis summary with HSIs and HUs by zone, average annual habitat unit tables for each restoration measure by zone, the annualized cost tables for restoration measures and real estate, copies of the interim CE/IA completed for reforestation and habitat improvement plant densities and materials, the Oxbow Center and Gateway East wetland complexes, respectively, and the Tandy zone, and a copy of the final study wide CE/IA.

FINAL ARRAY OF ALTERNATIVE BEST BUY PLANS. With 8 zones, 11 measures, and several possible scales for some measures (refer to Table 7), IWR-Plan analyzed over 15,728,640 possible combinations. Without-project inputs for the final analysis, by zone, are shown in Table 14. Final results determined that there were 162 cost effective plan combinations and 11 plan combinations considered to be "best buy" alternatives. The best buy plan results start with the combination plan that provides the greatest number of average annual habitat units (AAHUs) for the least cost and continues to the next plan combination that would increase the number of AAHUs for the next least cost increment until the final plan, which represents the greatest number of AAHUs that can be gained for the last added increment of costs. Table 15 provides a summary of the restoration measures identified in each of these combination plans, along with the AAHUs,

incremental AAHUs, annualized costs, incremental annualized costs, and incremental cost per output. Figure 9 is a graphic representation showing the AAHUs and annualized incremental costs for all the best buy plans.

Project Zone	Forested		Wetland		Grassland		Water		Disturbed	Existing Conditions Totals	
	Acres	HUs	Acres	HUs	Acres	HUs	Acres	HUs	Acres	Acres	HUs
Oxbow North	26.26	15.23	2.22	1.16	68.92	53.07	1.68	0.67	11.85	**110.93**	**70.13**
Oxbow Center	0.22	0.03	0.00	0.00	101.94	78.49	0.00	0.00	22.37	**124.53**	**78.52**
Oxbow South	0.29	0.16	3.08	1.60	29.17	22.46	0.00	0.00	1.47	**34.01**	**24.22**
Gateway Center	9.98	5.29	0.34	0.18	9.22	1.20	0.17	0.06	7.60	**27.31**	**6.73**
Gateway South	15.73	8.33	1.13	0.59	25.33	3.29	0.29	0.12	3.45	**45.93**	**12.33**
Gateway Beach	23.77	9.51	1.90	0.76	86.91	11.30	0.30	0.12	47.12	**160.00**	**21.69**
Gateway Park**	68.60	27.40	0.00	0.00	120.09	15.61	0.00	0.00	68.40	**257.09**	**43.01**
Gateway East	97.01	62.09	5.62	2.13	34.94	4.54	0.72	0.29	0.43	**138.72**	**69.05**
Tandy	59.87	24.55	0.80	0.00	90.27	44.23	0.00	0.00	7.71	**158.65**	**68.78**
TOTALS	**301.73**	**152.59**	**15.09**	**6.42**	**566.79**	**234.19**	**3.16**	**1.26**	**170.40**	**1,057.17**	**394.46**

Table 14. Summary of Acres and Habitat Units by Zone

*Adjusted based on constraints as described on pp. 97-103

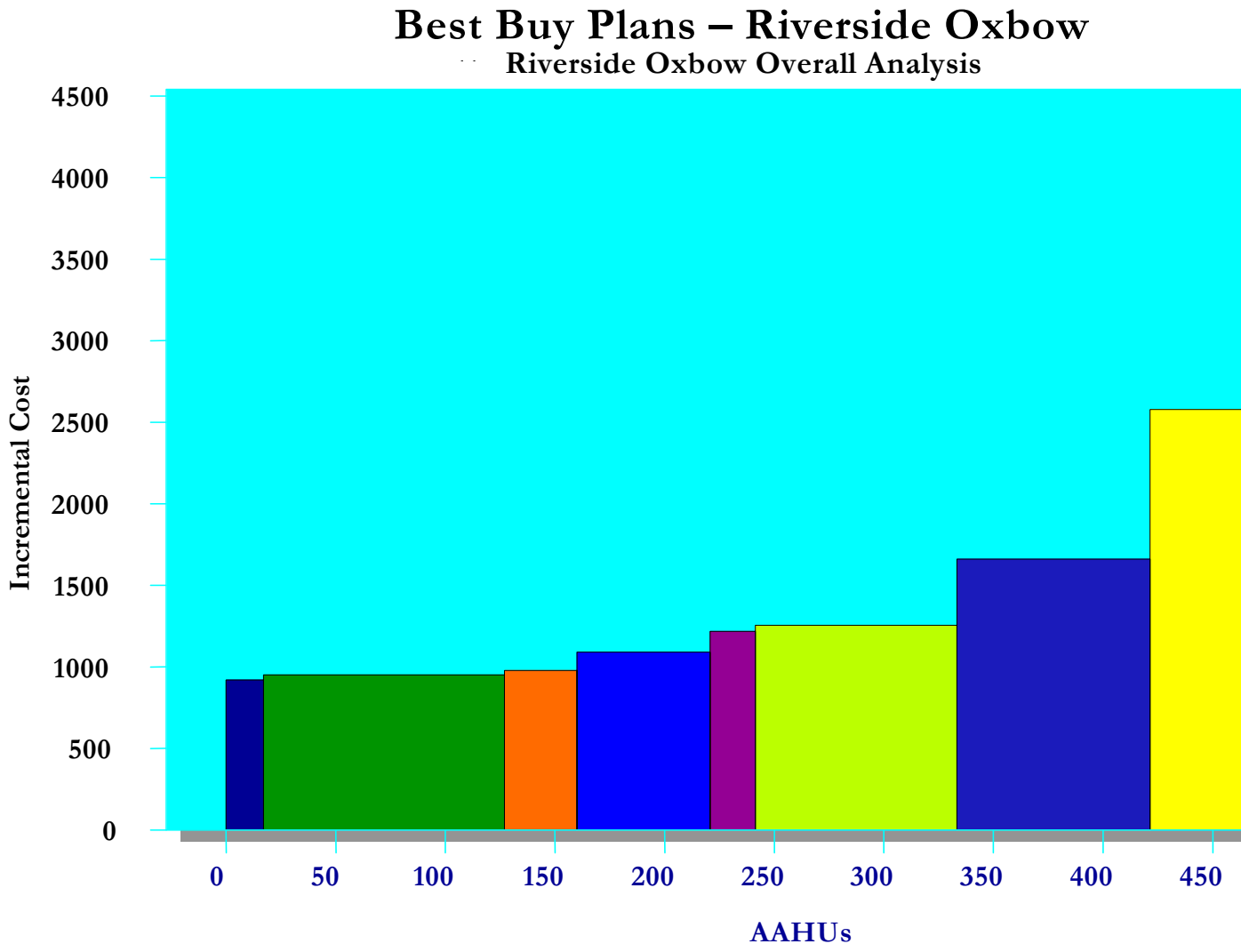
Table 15
Incremental Cost of Best Buy Combination Plans – Riverside Oxbow

Plans
Plan 1 - No Action
Plan 2 - Acquisition and restoration of Oxbow South
Plan 3 - Acquisition and restoration of Oxbow South and **acquisition and restoration of Gateway East**
Plan 4 - Acquisition and restoration of Oxbow South; acquisition and restoration of Gateway East; and **acquisition and restoration of Gateway South**
Plan 5 - Acquisition and restoration of Oxbow South; acquisition and restoration of Gateway East; **acquisition and restoratio of Gateway South**; and **acquisition and restoration of Oxbow Center**
Plan 6 - Acquisition and restoration of Oxbow South; acquisition and restoration of Gateway East; acquisition and restoration o Gateway South; acquisition and restoration of Oxbow Center; and **acquisition and restoration of Gateway Center**
Plan 7 - Acquisition and restoration of Oxbow South; acquisition and restoration of Gateway East; acquisition and restoration o Gateway South; acquisition and restoration of Oxbow Center; acquisition and restoration of Gateway Center; and **acquisition a restoration of Gateway Beach, including recontouring the wetland complex, adding quality wetland plants, water contr permanent water supply, and removing the old Gateway Entrance road**
Plan 8 - Acquisition and restoration of Oxbow South; acquisition and restoration of Gateway East; acquisition and restoration o Gateway South; acquisition and restoration of Oxbow Center; acquisition and restoration of Gateway Center; acquisition and restoration of Gateway Beach, including recontouring the wetland complex, adding quality wetland plants, water control, perman water supply, and removing the old Gateway Entrance road; and **acquisition and restoration of Oxbow North, including wat flow thru oxbow by removing earthen plug upstream, in-channel weir at confluence, and bridge at Beach along with a series of boulder clusters, planting, a 100-foot-wide native grass buffer strip along wooded riparian corridor, and replacing a water control in the North Pond along with restoration of 12 acres of native grass and tree mottes on the lan around the pond**
Plan 9 - Acquisition and restoration of Oxbow South; acquisition and restoration of Gateway East; acquisition and restoration o Gateway South; acquisition and restoration of Oxbow Center; acquisition and restoration of Gateway Center; acquisition and restoration of Gateway Beach, including recontouring the wetland complex, adding quality wetland plants, water control, perman water supply, and removing the old Gateway Entrance road; acquisition and restoration of Oxbow North, including water flow th oxbow by removing earthen plug upstream, in-channel weir at confluence, and bridge at Beach along with a series of boulder clusters, planting, a 100-foot-wide native grass buffer strip along wooded riparian corridor, and replacing a water control in the North Pond along with restoration of 12 acres of native grass and tree mottes on the lands around the pond; and **acquisition of the east portion of Tandy (east of Ben Street) along with restoration of the area by removal of invader species from grasslands and bottomland understory, adding native plantings to understory, and constructing perimeter fencing around Tandy east lands**

Table 15, continued.

Plans, continued
Plan 10 - Acquisition and restoration of Oxbow South; acquisition and restoration of Gateway East; acquisition and restoration Gateway South; acquisition and restoration of Oxbow Center; acquisition and restoration of Gateway Center; acquisition and restoration of Gateway Beach, including recontouring the wetland complex, adding quality wetland plants, water control, perman water supply, and removing the old Gateway Entrance road; acquisition and restoration of Oxbow North, including water flow tl oxbow by removing earthen plug upstream, in-channel weir at confluence, and bridge at Beach along with a series of boulder clusters, planting, a 100-foot-wide native grass buffer strip along wooded riparian corridor, and replacing a water control in the North Pond along with restoration of 12 acres of native grass and tree mottes on the lands around the pond; and **acquisition** of the east **and west portion of Tandy** along with restoration of the area by removal of invader species from grasslands and bottomland understory, adding native plantings to understory, **repair of erosion problems in west portion of Tandy and replanting with native grasses, and construct perimeter fencing on Tandy east and west lands**
Plan 11 - Acquisition and restoration of Oxbow South; acquisition and restoration of Gateway East; acquisition and restoration Gateway South; acquisition and restoration of Oxbow Center; acquisition and restoration of Gateway Center; acquisition and restoration of Gateway Beach, including recontouring the wetland complex, adding quality wetland plants, water control, perman water supply, and removing the old Gateway Entrance road; acquisition and restoration of Oxbow North, including water flow tl oxbow by removing earthen plug upstream, in-channel weir at confluence, and bridge at Beach along with a series of boulder clusters, planting, a 100-foot-wide native grass buffer strip along wooded riparian corridor, and replacing a water control in the North Pond along with restoration of 12 acres of native grass and tree mottes on the lands around the pond; and **acquisition of of Tandy** along with restoration of the area by removal of invader species from grasslands and bottomland understory, adding native plantings to understory, repair of erosion problems in west portion of Tandy and replanting with native grasses, **construction of perimeter fencing on all of Tandy lands, and removal of slab and parking lot on commercial properties, repair of slope erosion, and replanting with natives**

Figure 9
Best Buy Combination Plans for Riverside Oxbow Restoration Measures and/or Scales



Based on the incremental analysis, the study team determined that Plan 8, represented by the light blue bar in Figure 9, would be the combination plan recommended as the National Ecosystem Restoration Plan. The plan provides for the acquisition and restoration of a majority of the lands within the study area, except for lands eliminated from consideration for restoration efforts because of constraints or potentially incompatible future usage based on preliminary plan formulation as described earlier in this Plan Formulation chapter, and properties of the Tandy zone, which were removed from further consideration per policy guidance from USACE Headquarters. Table 16 summarizes the acres and habitat units for existing, future without- and future with project conditions by project zones based on implementation of Plan 8 as the NER plan. The changes in acreages and habitat units from Table 2 in the Existing Conditions chapter represent changes made during the plan formulation process.

Table 16
EXISTING A CRES AND HABITAT UNITS FOR
EXISTING, FUTURE WITH, AND WITHOUT PROJECT CONDITIONS

	Acres	HU s	Future Without Restoration (50 yr) AAHUs	Future With Restoration (50 yr) AAHUs
Oxbow North	104.90	67.38	23.57	88.11
Oxbow Central	85.1	54.4	10.99	60.56
Oxbow South	28.71	20.90	4.21	17.02
Gateway Central	27.30	6.73	3.93	20.75
Gateway South	45.93	12.33	3.57	33.11
Gateway Beach	138.00	18.38	10.09	91.93
Gateway East	138.72	69.05	63.48	109.97
TOTALS	**568.66**	**249.17**	**119.84**	**421.45**

IMPORTANCE OF PROJECT OUTPUTS. Bottomland and riparian woodland and wetland habitats are recognized as having national importance, due to their previous and continuing susceptibility to loss and because they are considered to have significant value for certain fish and wildlife species of national importance, such as migratory waterfowl and neotropical birds species that are protected by national and international treaties. One hundred and eighty nine species of trees and shrubs, 42 species of woody vines, 75 species of grasses, and 802 species of herbaceous plants occur in Texas' bottomlands. They are known to support 116 species of fish, 31 species of amphibians, 54 species of reptiles, 273 bird species and 45 species of mammals. At least 74 species of threatened and endangered animals depend directly on bottomland hardwood systems and over 50 percent of neotropical songbirds not listed as endangered or threatened are associated with these systems. Besides contributing to the biodiversity of Texas, and providing critical wildlife and bird habitat, bottomland hardwood systems with associated wetlands 1) serve as catchment and water retention areas in times of flooding; 2) help control erosion; 3) contribute to the nutrient cycle, and 4) play a vital role in maintaining water quality by serving as a depository for sediments, wastes and pollutants from runoff. Despite these important functions, bottomland hardwoods ecosystems are one to the most endangered ecosystems in the United States.

As noted in Table 16 above, the number of AAHUs in the project area under future without project conditions is 119.84 AAHUs, while the number for future with project conditions is 421.45 AAHUs. This means that under project conditions there will be a gain of 301.61 AAHUs over future without project conditions. Therefore, in addition to being consistent with State and Federal government initiatives to conserve and increase declining wetland acreage and the North American Waterfowl Management Plan with its goal of preserving and increasing North America's waterfowl population, implementation of the NER plan would increase the habitat value of the study area over 250 percent above the without project conditions. Specifically, the NER plan would restore or create approximately 56.5 acres of wetlands, improve the quality of the habitat on 179.7 acres of bottomland hardwood and mixed deciduous forest stands, reforest 66.9 acres of open space to bottomland hardwoods, restore 206.9 acres of native floodplain grass prairie, restore

45.6 acres of native grassland buffer and create 13.1 acres of open water, in addition to restoring flow back through the oxbow. Subsequently the remaining acres of existing habitat within the study area become more valuable by reducing the fragmented nature of the existing habitat and restoring a contiguous corridor for migration of avian and wildlife species through the area. The NER plan directly addresses the loss and scarcity of resources as described above as well as complements various local, regional, state and federal plans for restoring and preserving resources. In addition, the plan fulfills the objectives that were identified by the study team during the plan formulation process.